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52nd Annual Meeting

Cincinnati, Ohio
June 22–25, 1944

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The Cincinnati Meeting
June 22-25, 1944

By CLYDE W. PARK

Just now nearly every one is asking, "What is ahead in education?" For a large section of the college public the question is, more specifically, "What is ahead in engineering education?" The latter question, with all its ramifying aspects, is the central subject of the fifty-second annual S.P.E.E. convention, to be held at Cincinnati, June 22–25, 1944. This timely theme will be emphasized, not only in the keynote address on "Education After the War," by President Robert E. Doherty, but also in other general sessions, including one on "Guidance and Measurement," and in the many divisional conferences which complete the program of an exceptionally interesting and important meeting.

Because of transportation difficulties only one general session, that of Friday, June 23, at 2:00, will be held on the campus of the host institution, the University of Cincinnati. The other meetings will be held either in the large Hall of Mirrors or in conveniently located rooms adjacent to it on the third and fourth floors of the Netherland Plaza Hotel, which is headquarters for the convention. Immediately adjoining the Hall of Mirrors also are the registration and information desks and the lounge which has been reserved for women.

The main sessions will begin with an address of welcome by Raymond Walters, President of the University of Cincinnati, and a Presidential Address by Robert E. Doherty, President of the Society and of the Carnegie Institute of Technology. At the second general session, under the leadership of Vice-president A. R. Cullimore, a paper will be presented by R. C. Gowdy, Dean of the College of Engineering and Commerce, University of Cincinnati, on "Selection and Guidance Aspects of Coöperative Education." "Measurement and Guidance Project" from the standpoint of S.P.E.E., E.C.P.D., and the Carnegie Foundation, will be discussed by R. L. Sackett, Pennsylvania State College; Kenneth W. Vaughn, the Carnegie Foundation; and R. H. Frazier, Massachusetts Institute of Technology. At the Saturday morning session the subject of "Engineering Education After the War" will be presented by H. P. Hammond, Pennsylvania State College; H. S. Rogers, Polytechnic Institute of Brooklyn; and C. E. MacQuigg, Ohio State University. A discussion from the floor will follow. The annual dinner will be held on Saturday evening, June 24. The speaker will be F. V. Geier, President of the Cincinnati Milling Company.

Cincinnati is well known as a center of industrial activity and engineering research. Under normal conditions the plants and processes of several firms would justify inspection trips by large groups of delegates. Although war-time restrictions and transportation difficulties prevent the planning of visits by large

groups, an effort will be made to arrange trips for individuals and small parties who wish to investigate specific industrial processes. Inquiries concerning such visits will be handled by the local committee on hospitality.

Besides a series of events planned for women attending the convention there are numerous opportunities for them to find pleasant and profitable entertainment. Shopping and theatre-going will readily suggest themselves. The Cincinnati Zoological Garden, the Rookwood Pottery, The Cincinnati Art Museum in Eden Park, and the Taft Museum in downtown Cincinnati will appeal to many visitors. A river trip to Coney Island or a trolley ride to points in Kentucky can easily be arranged. Those who remain until Sunday evening, June 25, will probably wish to reserve seats for the opening performance of the Cincinnati Summer Opera Company. Details concerning this and other entertainment possibilities may be had at the information desk.

Report of Committee on Engineering Education After the War

Engineering education, in common with all other activities of the Nation at present, is being powerfully influenced by the war. Many of these influences are likely to continue into the period of readjustment that will follow. It is even possible that some of them may be lasting and that the pattern of engineering education may thus be permanently modified. The whole realm of higher education is in a state of flux. During such a period conditions susceptible of control may be so misjudged as to be permitted to cause lasting damage. On the other hand, they may be so controlled as to avoid injury or so guided as to yield permanent benefits. It was considerations such as these that led to the appointment of this committee.

The committee has been directed to study the urgent problems of the immediate future as well as longer range problems of educational principle and practice, and particularly to review the 1940 Report on Aims and Scope of Engineering Curricula in the light of future conditions as they can now be envisaged. The committee has been directed specifically to study the need, as made clear by the issues of the war, of creating among engineers an understanding of the social and economic world they live in and have had so large a share in creating.

The 1940 Report on Aims and Scope of Engineering Curricula advocated the strengthening of engineering education by concentration on basic elements in the undergraduate years, organization of the curriculum in parallel integrated sequences of scientific-technological and humanistic-social subjects, and by transfer of some of the more specialized subjects to the postgraduate period.

The exigencies of war have tended to cause a reversal of the process embodied in these recommendations. Special war training programs of limited duration must necessarily be concentrated on the attainment of specific technical objectives. Even their basic phases include only such general studies as have a direct relationship to military requirements. No one will question the necessity of training men for military service by intensive methods in time of war. We believe, however, that with the cessation of hostilities the policy of expediency in engineering education should be abandoned. The evolutionary process of strengthening engineering education at its base should then be resumed as quickly as possible.

In attacking its assignment the committee considered first, matters of general policy. These are discussed in Part I of this report.

Specific problems of the post-war period are then considered in Part II. These include the adjustment of curricula to the needs of returning vet-

erans, the adaptation of the college calendar to the post-war transition period, the possible effects of future universal military service, the rehabilitation of faculties, the restoration and strengthening of postgraduate study and research, and the study of lessons learned from war experiences that may be applied to the permanent benefit of engineering education.

The committee comprises 21 members and has held two general meetings. A smaller group of members has met at other times to prepare drafts of the report. These have then been reviewed by the entire committee. A version prepared by this process has been circulated among a large group of educators both in and outside of engineering education. The report, therefore, is the result of a long process of preparation and embodies the ideas of many persons.

The committee recognizes that a report can do no more than discuss problems, state principles, and make recommendations. It remains for the great body of those who conduct engineering education or are interested in it to take action. The committee earnestly hopes that one of the chief results of the report will be to stimulate discussion of the matters here presented at meetings of college faculties and professional engineering societes, and that the results of such discussions may be disseminated widely.

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PART I

PURPOSES AND PROBLEMS OF ENGINEERING EDUCATION

The purposes and problems of engineering education hinge on its two major responsibilities. One of these, which determines its aims and standards, is to the public, industry, and the profession it serves. The other, which determines its methods, is to the students as individuals. It is responsible to the public for seeing to it that the students emerge from college with an attitude and background appropriate to effective citizenship as professional men, and that they shall have acquired a sustaining interest in the common welfare and the cultural aspects of community life. Engineering education is responsible to industry for educational programs suitable for professional personnel in engineering and management, and to the engineering profession for the maintenance of proper educational standards and the inculcation of ethical attitudes and conduct among its graduates. Finally, it is responsible to

the students themselves for an educational program in which they will be treated as individuals and helped to achieve maximum development of mind and character.

The specific purposes implied here are of broad scope and are essentially those recommended in the 1940 Report on Aims and Scope of Engineering Curricula. They include training in the sciences basic to engineering, the rudimentary development of certain technical skills, an introduction to the engineering method of solving problems of practice, an understanding of values and costs, a sense of the art of engineering as distinguished from its science, the ability to read, write, and speak the English language effectively, a knowledge of social and human relationships, an understanding of the duties of citizenship, an appreciation of cultural interests outside the field of engineering, and indoctrination in professional standards and relations. Inherent in the accomplishment of these purposes is the development in the student of habits of accuracy and thoroughness, powers of analysis, creative ability, respect for facts, and high standards of integrity with respect to all aspects of his work.

Among the problems involved in the accomplishment of these purposes, perhaps the most difficult one is the limitation of time, especially in view of the conditions set at the beginning and the end points of the curriculum.

On the one hand, the level of beginning is set by the secondary schools. While efforts are being made to insure more adequate preparation of students and greater selectivity in admitting them, the early stages of the undergraduate curriculum are likely to continue to be essentially introductory in nature; the early semesters will have to be directed to an important extent to developing ability to study effectively, to think quantitatively, and to execute systematically. Experience in the Army and Navy training programs has disclosed that even when students are selected on the basis of high scholastic aptitude the necessity remains of devoting a great deal of time and effort to adjusting them to the conditions of collegiate study, especially in science and engineering.

On the other hand, the terminal point is set by the obligation assumed by engineering schools themselves that by the time of graduation their students will have achieved the knowledge, abilities, and attitudes referred to above. To help the student, starting at the high-school level, to achieve these ends within the time available imposes a problem that can be solved only by the most careful planning in which the strictest attention is given to the adopted objectives and only such subject matters and procedures are included in the curriculum as are essential to their attainment.

The above paragraphs and the 1940 Report identify the purposes and problems of engineering education as a whole and indicate for the great body of engineering students goals that seem possible of attainment in the near future. We feel justified, however, in going a step further by discussing certain trends that seem to point to the adoption of additional modifications of educational programs, as soon as may be practicable, for certain special groups of students. One of these trends is the increase in the application of the engineering method in the management and operation of industry as evidenced by the phenomenal increase in the use of engineering graduates in these fields of activity. A second

clearly evident trend is the greatly increased need for engineers prepared to practice at high scientific and creative level. It is a matter of vital concern to the nation in relation both to security and economic welfare that the highest levels of scientific and engineering excellence be maintained at all times. We believe that the special needs of students to be prepared for service in accordance with these trends should be met by provision of curricula different from those offered for the great majority referred to above. Thus plans should be laid for three major groups of students:

1. Those who would follow engineering programs of the usual pattern, but modified as indicated elsewhere herein and in accordance with the objectives of the Report of 1940. This group would continue to comprise a majority of undergraduate engineering students.
2. Those preparing for careers in the operation and management of industry.
3. Those who would be fitted for unusual scientific and creative accomplishments.

Curricula provided for all three groups should possess the elements that are common to all genuine engineering programs, that is, emphasis on the engineering method and sound preparation in physical science and engineering fundamentals. Without these elements a program does not belong in a school of engineering.

For all of the programs mentioned, we believe that the first three years should conform to customary patterns, modified in general characteristics as suggested elsewhere in this report, and with variations in subject matters of physical and engineering science in accord with the several major branches of engineering. After the third year, however, more fundamental differentiation would begin. For the first two groups—regular students and the industrial group—professional subject matter would be different in nature and functional purpose. The industrial group would give major attention to matters relating to production and operation, while the regular group would concentrate on scientific-technological studies. The content of humanistic-social studies would be the same for both groups as would the total duration, generally four academic years, required for the award of the baccalaureate degree.

The program for the group preparing for highly scientific and creative engineering work should be differentiated from the other programs not later than the end of the junior year in order to provide broader and more fundamental preparation in scientific principles and methods than is needed for the general run of students. This program would of necessity be longer in duration than the others and would extend from the end of the junior year through one or more years of graduate study leading to the master's or doctor's degree. The curriculum should be *planned as a unit* comprising two or more years and thus requiring for completion a total of at least five years from time of admission to college. This program is referred to again under "graduate work."

It may be well at this point to review the purposes of engineering education which we reaffirm, as recommended in the Report of 1940. Two major divisions are to be recognized: (1) the scientific-technological, and (2) the humanistic-social. The objectives of the scientific-technological division are:

1. Mastery of the fundamental scientific principles and a command of basic knowledge underlying the branch of engineering which the student is pursuing. This implies:
   (*a*) grasp of the meaning of physical and mathematical laws, and knowl-

S.P.E.E. Committee on Engineering Education After the War.

Reading from left to right. Front row: C. E. MacQuigg, F. T. Mavis, Neil McKenry, Robert E. Doherty, H. P. Hammond, *Chairman*, H. S. Rogers, W. E. Wickenden, D. B. Prentice. *Back row:* A. R. Stevenson, J. W. Barker, E. L. Moreland, C. R. Young, F. L. Wilkinson, H. T. Heald, E. S. Burdell, B. R. Teare, F. L. Bishop, W. R. Woolrich. Members of the Committee unable to attend meeting: F. G. Higbee, Sidney Kirkpatrick, B. M. Woods.

edge of how they were evolved and of the limitations in their use;
(*b*) knowledge of materials, machines, and structures.

2. Thorough understanding of the engineering method and elementary competence in its application. This requires:
(*a*) comprehension of the interacting elements in situations which are to be analyzed;
(*b*) ability to think straight in the application of fundamental principles to new problems;
(*c*) reasonable skill in making approximations, and in choosing the type of approach in the light of the accuracy required and the time available for solution—in sum, a foundation for engineering judgment;
(*d*) resourcefulness and originality in devising means to an end;
(*e*) understanding of the element of cost in engineering and the ability to deal with this factor just as competently as with technological factors.
3. Ability to select the significant results of an engineering study and to present them clearly and concisely by verbal and graphic means.
4. Stimulation of a continuing interest in further professional development.

The objectives of the humanistic-social division are:

1. Understanding of the evolution of the social organization within which we live and of the influence of science and engineering on its development.
2. Ability to recognize and to make a critical analysis of a problem involving social and economic elements, to arrive at an intelligent opinion about it, and to read with discrimination and purpose towards these ends.
3. Ability to organize thoughts logically and to express them lucidly and convincingly in oral and written English.
4. Acquaintance with some of the great masterpieces of literature and an understanding of their setting in and influence on civilization.
5. Development of moral, ethical, and social concepts essential to a satisfying personal philosophy, to a career consistent with the public welfare, and to a sound professional attitude.
6. Attainment of an interest and pleasure in these pursuits and thus of an inspiration to continued study.

Experiences of the war have in no way altered our belief in the validity of organization of the undergraduate curriculum in two parallel stems embodying these divisions of study and subject matter and coördinate in their bearing on the student's total development.

Means of Achieving the Purposes of the Curriculum

It is not sufficient, however, merely to recognize the purposes of these two curricular stems; it is necessary also to establish the *means* for achieving their educational objectives. Explicit objectives must be formulated not only for the major portions of the curriculum but also for each of its subdivisions in terms of knowledge to be acquired and abilities to be achieved. The committee realizes that no existing formulation of means—of educational programs and procedures—has as yet proved to be fully adequate in achieving these objectives. We believe that a year-by-year development of such means is one of the most important tasks before this Society. A few suggestions are proposed as a preliminary basis for the *design of a plan* for guiding the student's development.

Division of Time.—One suggestion relates to the allocation of the student's time as between the scientific-technological and the humanistic-social stems of the curriculum. While it is clearly recognized that the scientific-technological studies must receive a preponderant allotment of time, it is also evident that adequate time must be allocated to the humanistic-social studies if the objectives are to be reasonably well achieved. We believe they cannot be achieved through a three-

hour course in English in the freshman year plus a three-hour course in economics in the sophomore year; that they can be achieved only through a *designed sequence* of courses extending throughout the four undergraduate years and requiring a minimum of approximately 20 per cent of the student's educational time. This allotment should be at least equivalent to one three-hour course extending throughout the curriculum, and on the average somewhat more.

The Humanistic-Social Stem

Methods of Organization.—The positions taken in the 1940 Report constitute a definitive collective judgment on the goals of the humanistic-social area of engineering education. If, as is now suggested, the equivalent of about one academic year is allotted to this area, it will mark a substantial advance in most engineering curricula. None the less, the result even under favorable conditions seems likely to be somewhat less adequate than in other areas.

It may be appropriate, therefore, to summarize in as pointed terms as present experience will sustain the conditions which may make for the most effective result within the limits of time and personnel generally available:

1. *Establish responsibility* for planning and coördination; merely parcelling out time to isolated departments has generally led to unsatisfactory results. If responsibility cannot be established through the customary type of department headship, it may be necessary to do it through administrative direction, at least until the aims of the program are recognized and the work soundly established. A similar focal point of responsibility in the humanistic-social area is needed in this Society.
2. *Formulate the results sought* as explicitly as possible; select appropriate materials with discrimination; and arrange them in a unified, developing sequence extending through the curriculum.
3. *Discriminate between humanistic studies and business training.* Economics, sociology, government, history, and psychology are sciences of human behavior and relations, while accounting, for example, is a technical subject closely related to engineering cost analysis.
4. *Allot time in more advanced years* as generously as possible. The interests of engineering students are likely to center on technical subjects in the earlier years. As students become more mature in later years their interests in social, cultural, and philosophical matters are, we believe, more readily aroused and developed.
5. *Enrich this area of work* by use of whatever time may be gained by individuals or groups through higher entrance levels in mathematics, science, drawing, and ordinary language skills.
6. *Use the most skillful teaching available.* Erudition is a secondary consideration; mental maturity, perspective, sympathetic perception of the student's present viewpoint and of his career aims, interpretive ability, and ability to awaken interest and elicit active participation are primary. The teacher must exemplify the matters he teaches in traits of personality and in personal competence.
7. *Capitalize on the appeal of current interest.* Many engineering students, especially in early years, are more readily interested in contemporary literature than in the classics and respond better to the history of the modern world than to the evolutionary history of scientific ideas or of social and political institutions.
8. *Reinforce curricular work by voluntary student activities.* Encourage engineering students to participate in expressional activities (music, dramatics, public speaking, painting, etc.); and in student organizations concerned with public and social problems; provide organized opportunities for attending the theatre, concerts, art exhibits, etc., and assign themes and reviews based on these events.

Responsibilities of Citizenship.—The duty of citizenship in a democratic society is one which an engineer may fulfill in part as an individual and in part through his participation in the group activities of his profession and community. The training and experience of his student days should lay foundations for both types of competence. It seems clear that engineers, as part of this professional duty, must assume a more important share in shaping public policies and practices, and especially so in areas related to their work.

Among the roles of citizenship, four aspects may be recognized:

1. Observance of laws and regulations.
2. Sustaining participation in government and in cultural activities.
3. Criticism and counsel.
4. Creative contributions as statesmen, thinkers, artists, philanthropists and leaders of social movements.

Obviously engineers will not assume the more conspicuous critical and creative roles except in relatively few cases. On the other hand, engineers should be counted in full proportions among groups which read books, discuss ideas, hear music, attend the theatre, appreciate works of art, sustain churches, advance philanthropy, man welfare activities, serve as trustees, and lead civic movements.

The acquisition of definable knowledge, while not the primary means to this end, is in no sense unimportant. It is not too much to expect the engineer, in addition to a satisfactory level of general literacy, to have an elementary critical understanding of the philosophy of the democratic state and of the economics of private and public enterprise, and an appreciation of the contributions of science and technology to industrial progress and the general welfare. He should also, as a guide to critical, ethical, and moral values, have some acquaintance with the great enduring humanistic ideas which men have evolved.

Attitudes, emotions, feelings, and beliefs are among the primary forces motivating conduct and behavior. These are obviously the fruit of nurture and indoctrination, but may be brought to effective maturity as they are refined by critical thought, by experience, and by faith. The role of the college in these processes of nurture and refinement, while not easily defined, is none the less real and insistent. The natural detachment so desirable in science will not suffice in the humanities nor in certain of the social studies, where concepts of value and motivation of social conduct are involved.

These concerns can be expressed only partially in the curriculum. Continuous cultivation by precept, by example, and by participation in campus activities of civic value deserves equal emphasis.

Program and Methods of Instruction.—While the selection of subject matter suitable to the achievement of the aims of humanistic-social studies is important, we believe that this will present less difficulty than will devising appropriate methods of instruction.

The subjects usually, and we believe properly, associated with the humanistic-social stem of the curriculum are found in the fields of history, economics, and government, wherein knowledge is essential to competence as a citizen; and of literature, philosophy, psychology, and fine arts which afford means for broadening the engineer's intellectual outlook. Any particular program must of necessity be built within the framework of conditions which can

be established and with the personnel available.

We believe, however, that knowledge of miscellaneous details of the subject matter selected is less important for engineering students than is the acquirement of the ability to understand, to analyze, and to express the essentials of an economic, social, or humanistic situation or problem, and to appreciate the implications and relationships of such problems to the life and work of an engineer.

Formal expository methods are often used in these fields. We believe they are less effective in accomplishing the results advocated than a method which places responsibility on the student himself. Such a method should require him to read, to question, to seek evidence, to weigh, to judge, to accept, and to express the results of his efforts in written or oral form both in school and in life situations. It will also require greater effort and skill on the part of the instructor as well as a more generous allotment of assigned teaching time than is customarily given to this portion of the curriculum. Finally, it will require careful nurture and direction on the part of both faculty and administrative leaders.

The Scientific-Technological Stem

Emphasis in Curriculum Organization.—The mere enumeration of the aims and purposes of engineering education makes clear the difficulty of achieving them in the limited time available with young men of varied preparation and capacities who have inadequate general knowledge of the nature of engineering. The inference is plain that the entire educational program must be scrutinized with the view to eliminating all unimportant elements and concentrating on those of primary importance. It is especially clear that the attempt to make the undergraduate student proficient in specialized subdivisions of engineering practice must be abandoned in the interests of developing mastery of basic principles.

The 1940 Report on Aims and Scope of Engineering Curricula presented, and this committee reaffirms, the following general recommendations for carrying the foregoing proposals into effect:

> Undergraduate curricula should be made broader and more fundamental through increased emphasis on basic sciences and humanistic and social studies. This will require greater efficiency in the use of the student's time to be gained by pruning to the essentials of a sound educational program.
>
> Some of the advanced technical subject matter now included in undergraduate curricula should be transferred to the post-graduate period where it may be pursued with a rigor consistent with preparation for engineering specialization.

Tools of Scientific-Technological Thought.—A sound program of objectives for scientific-technological studies must include both the development of mastery of the fundamentals and rudimentary facility in their application. These two associated elements—critical understanding and power of constructive application—are complementary. One may not possess either in any considerable degree without the other.

We believe that the attainment of mastery of fundamentals is influenced greatly by the proper selection of subject matters, while the development of power to apply them is influenced most by the method of instruction. It must be recognized that this mastery and power are not separate entities but different aspects of the same thing—the process of engineering thought.

The evolution of engineering thought and of engineering practice has given us a body of knowledge based upon facts and principles that may be classified in five broad categories:

1. *Generic principles,* including such basic concepts as the law of conservation of energy.
2. *Basic assumptions,* such as "plane sections before bending remain plane after bending," which are made for the purpose of simplifying the mathematical analysis of physical phenomena.
3. *Empiricisms,* such as the properties of materials which have been observed and measured in the laboratory.
4. *Derived principles,* or working formulas, such as the flexure formula, which have been developed in various fields of practice.
5. *Specifications and standards, or codes of practice.*

These principles, assumptions, empiricisms, standards, and practices are the working tools of the engineer. They are presented in courses which differ in their emphasis. Generic principles and basic assumptions are traditionally presented in such fundamental courses as physics, mechanics, hydraulics, electrical circuits, and thermodynamics. Critical understanding of them rests primarily upon *recognition of their underlying physical concepts.* These are frequently so obscured by the presentations of textbooks and teachers that students may accept them merely as algebraic statements or formulas to be remembered. There is great opportunity to vivify the presentation of these concepts through graphical methods and laboratory demonstrations. It is essential that major principles and concepts *be presented in connection with physical situations* in such a way that the student will learn to recognize the elements of similar situations that are new to him and thus be able to identify the principles that are involved. There are relatively few such principles and concepts but they are applicable to problems in many fields. We believe that an appreciation of this underlying unity in the field of physical science is essential.

Empiricisms are best presented and studied in the laboratory. Most of them have definite limitations within which they may be applied. It is very important that students understand the origin and limitations of empirical data and principles.

Derived principles and specifications and standards have evolved in the development of technology and of the arts of engineering practice. They are generally presented in such applied courses as electrical machinery, heat power, and structural design. While the emphasis in basic courses should be upon critical understanding, in applied courses emphasis should shift toward facility in the use of derived principles. It is most essential, however, that even here students thoroughly understand the origin and limitations of working data and formulas. In using a formula they should be required to identify the principles and assumptions from which it was derived.

In the long run, however, facility in the application of principles, either generic or derived, to the solution of new problems is based upon a critical understanding and a conscious recognition of these tools of engineering thought. No other one thing ties the engineering profession more closely together than this way of thinking.

The Art of Engineering.—The subdivisions of knowledge enumerated above constitute the subject matter of engineering study. Knowledge of these tools, however, does not constitute ability to practice engineering. There remains the necessity for the young engi-

neer to integrate the application of these laws, assumptions, data, and codes so as to accomplish a desired result safely and economically. This requires a combination of resourcefulness, skill, experience, and judgment—amounting at times almost to intuition—which we call the *art* of engineering. Judgment matures only through experience, but introduction to the art of engineering and the development of judgment—in other words, elementary competence in the engineering method—can and should begin in college. Unless instruction includes the elements of the arts of practice, it will be in science rather than in engineering. Throughout the whole fabric of engineering education, therefore, there must be interwoven with instruction in scientific principles, the development of rudimentary skills of execution, understanding of the limitations in the application of principles to practical situations, the beginnings of powers of decision and of judgment, the encouragement of creative talent, ability to deal with the factor of values and costs, and the acquirement of that appreciative sense which is satisfied only by skillful execution or precise verbal expression.

The significance and nature of the art of engineering practice cannot be conveyed completely in any single subject of instruction; it should be inherent in greater or less degree in all engineering courses. In advocating the broadening and strengthening of the scientific and humanistic base of engineering education we are equally conscious of the need to retain and enrich this element in the education of engineers.

Instructional Procedures.—Methods of instruction will and should vary with individual teachers, but certain common characteristics of sound instructional methods in engineering can be identified. Some of these characteristics are here stated with the purpose of stimulating further discussion:

1. Engineering education possesses the great advantage of employing three processes of instruction: lecture-recitation, laboratory, and design. The advantages of each should be capitalized. When two or more methods are employed in a given division of subject matter they should be coördinated. Advantages to be gained by treating a given subject in a single unified course are often lost when the work is handled in separate recitation, laboratory, and design courses.
2. In engineering, learning is best achieved by doing. Knowledge acquired by merely being receptive to the efforts of the teacher is not likely to be permanent. The process of "having the teacher recite the lesson for the class" is a poor method of instruction. The problem method is most effective for the mastery of elementary principles, and the project method for the integration of thought procedure and of practice in the development of the art of engineering.
3. Dealing with students individually is more effective than dealing with them in groups. Correction of individual mistakes, overcoming individual weaknesses, developing individual strengths—a process possible only when class sections are relatively small and instructors' loads reasonable—is conducive to better results than less individual methods. However, the provision of small sections and light loads merely creates the conditions under which good instruction can be given. Observation indicates that the lecture method is used almost as often in small classes as it is in large ones. Unless the individual teacher takes advantage of the opportunities for individual instruction that small class sections afford the extra cost is wasted.
4. Each course should be designed as an integrated whole, not as a mere assembly of loosely related subject matters. And it should be closely related

in content and method to other courses in the same general field.

5. Students should be acquainted with the reasons for each course and its purposes at the beginning, and means should be afforded to them to appraise their own achievement of those purposes. Progress toward mastery and competence should be recognized and rewarded.

Instruction in the Engineering Method.—The engineering method should be emphasized in all scientific-technological courses. However, in many of them it may be lost sight of by being subordinated to subject matter. The engineering method implies a breadth of understanding which it is difficult to develop to the fullest in a course devoted to a specific subject. Hence there are advantages to be gained in a course having as the *primary purpose* the development of a method of approach, and in which the situations to be analyzed are not restricted to a single subject, but involve several fields. The following is a description of an existing course, Engineering Analysis, which has this purpose and is, in effect, an introduction to the engineering method.

This course is a special kind of problem course. In the first place, it is special in that the emphasis is not so much on subject matter as on method. Secondly, the course is characterized by cutting across the boundaries of academic subjects. Problems are drawn from different subjects, and individual problems may involve principles from a number of fields. Finally, the course gives the student a review and the opportunity of understanding the principles from the various fields as parts of an organized pattern; and it gives the instructor the opportunity of discovering and remedying deficiencies in students' backgrounds.

The choice of problems in such a course is of the utmost importance. The first problems are drawn from mechanics, because mechanics problems are easy to visualize, and mechanics concepts underlie those of heat and electricity. A suitable problem is one that presents an engineering situation relatively new to the student and one whose solution is to be obtained not by substitution in formulas, but by the application of fundamental principles. Since the problem is built around an engineering situation it must be studied to see what the important elements are, a method of solution must be selected and applied, and usually simplifying assumptions must be made. Finally the solution must be checked as carefully as possible and engineering conclusions drawn.

As important as the type of problem is its degree of difficulty. Good engineering problems may be found at all levels, but a problem that is too easy or too difficult is of little educational value. A problem should be hard enough to tax the student's intellectual powers and give him a feeling of achievement when he has obtained a solution, yet not so difficult that he is discouraged. A given problem may be suitable at one level of progress, too difficult at an earlier time, or too easy if assigned later. Thus it is important not only to select good problems, but also to assign them at the right times.

In the course here described classes are conducted so as to promote the maximum of student participation. The instructor and the class, working together, develop a methodical approach to new problems, review scientific principles that are being used, work problems as examples, and discuss student solutions. In general, lectures are avoided. Blackboard work provides an opportunity for each student to work individually with help and criticism from the instructor. Originality is encouraged, and original solutions by students are brought to the attention of the class.

In summary, the course in Engineering Analysis is pointed toward the method of solving problems that are new to the student and are at the right level of difficulty. The subject matter is broad and, like practical engineering problems, cuts across boundaries of academic subjects and involves principles from several fields.

Discipline in Engineering Habits of Work.—In most instances, students en-

tering upon engineering study must first learn to work; that is, to study and to execute. While the student is acquiring this ability the teacher must control the process. Assignments must be short range and problems should usually involve only a single principle. At the outset, disciplinary training to establish habits of industry, thoroughness, orderliness, and accuracy is no less important than the study of new fields of subject matter. As the student progresses from term to term the degree to which he can be expected to accept responsibility and exercise his own initiative should increase and closeness of supervision should change correspondingly. Toward the end of the curriculum the student should be able to walk by himself along the educational path—and he should be expected to do so. This implies that as the student advances, work assignments should become progressively more comprehensive. Toward the end of the curriculum problems should attain the dimensions of projects. The process employed in architecture wherein the student works on problems of design of increasing complexity might well be employed to a greater extent in engineering. This method of instruction is more difficult for the teacher than the method of day-to-day assignments, and it is likely to consume more of the student's time. We are convinced, however, that it will lead to better mastery of subject matter and greater self-reliance and initiative.

Cultivation of Creative Ability.—The development of creative ability is largely neglected as an explicit objective of engineering education. We believe it should have a recognized place in the undergraduate curriculum. Design courses of the project type and the undergraduate thesis are especially appropriate for this purpose. The fostering and development of initiative and originality should not be limited, of course, to any particular phase of the curriculum. It should be an objective of all engineering instruction.

We suggest that means of promoting creative ability be made a matter for consideration by this Society and that it be discussed both in committee and in general meetings.

Measurement of Achievement.—The committee urges the setting up of standards of proficiency based on achievement of defined objectives. At the end of each course and of each division of the curriculum the degree to which the student has *achieved his objectives* should be carefully measured. Such measurements will differ from the usual course examinations; in accordance with the objectives, they will test to a lesser degree retention of subject matters and miscellaneous formulas, and to a much greater degree understanding and the ability to *do—i.e.*, to think one's way through, to complete a project, to express a thought. Thus as the student progresses the measurement of his achievement should become increasingly comprehensive, involving projects of greater scope which tax his creative powers and initiative. Such standards of proficiency will place less emphasis upon extent of subject matter covered; they will emphasize mastery and power to perform independently.

Recruitment and Development of Faculties.—Realization of the objectives of this report will depend in large measure on the effectiveness of engineering faculties. The rehabilitation of these groups from the impairment caused by war is discussed elsewhere in this report (see Part II, page —). However, there are other factors re-

lating to the effectiveness of teaching staffs that are not dependent upon war conditions.

First of these in importance is the necessity of painstaking selection of teachers of all age levels and ranks. While care is usually exercised in choosing teachers for the higher faculty posts, instructors and assistants are appointed too often on the basis of expediency instead of the criterion of eventual development to fill important positions. Whether or not the principle of tenure is applied always in the best interests of faculty effectiveness, it is a condition to be reckoned with, and appointments should be made with the possibility of permanency in mind. Good administrative practice will aim to insure a steady progression of able young men from among whom higher faculty positions can be filled as vacancies occur or new positions are created.

During the decade immediately preceding the war, increasing numbers of able students were pursuing graduate courses in engineering. An abundant supply of promising teachers was beginning to be available from this source and there was prospect that in comparatively few years better engineering faculties would be assembled than ever existed before. It is of the utmost importance that this situation be reëstablished at the earliest possible moment. In the meantime, it is important that long-term appointments be made only of those who could qualify under the most favorable conditions of faculty recruitment that may be created in the future.

A second need is for the systematic development of skill in teaching among younger faculty members and the creation of opportunities for broadening the experience of those whose professional environment has been limited to the classroom and the teaching laboratory. Too often, this is a neglected phase of faculty development.

While this committee cannot lay down patterned procedures for accomplishing these tasks, we would emphasize that it should be accepted as the responsibility of engineering college administrators to establish and direct programs of orientation and development for new and younger members of faculties and to aid in securing opportunities for faculty participation in broadening professional practice.

Instruction and Research as Complementary Phases of the Work of Engineering Colleges.—Institutions of higher learning should serve two purposes: (1) Instruction in the existing knowledge of science and the arts, and (2) creation and dissemination of new knowledge. These two purposes are of comparable importance and should be served with equal effectiveness in engineering colleges. These institutions, collectively, should serve as the chief agency for the training of research workers in applied science and for conducting basic technological research. They should also supply research services for industries that do not provide their own research facilities.

Research in engineering colleges is important also as a means of developing a creative environment for the student and a spirit of inquiry and powers of originality among members of the faculty which will be reflected in the classroom.

While instruction in engineering colleges has advanced in this country to a position of recognized strength, an equally strong development of research has been accomplished in relatively few institutions. This is one of the most serious shortcomings of the entire

realm of engineering education. It is one to which all concerned should address themselves as soon as normal educational conditions are reëstablished.

In reference to one aspect of research activities as a function of engineering colleges we would repeat one cautionary statement often made before; namely, that genuine research in engineering and science is one thing, routine testing is another. Routine testing which has no scientific interest and does not promote the qualifications of the individuals concerned but is merely conducted for remuneration should have no place in the work of an engineering college, unless, of course, some definite obligation exists, as on the part of a publicly supported institution to some other public agency, or unless no other testing facilities are available.

Cultivation of the Ideals and Obligations of the Engineering Profession.—The cultivation of professional ideals and obligations is assuming increasing importance in the education of engineers because of the growing organization of society into functional groups. Among the characteristics of professional indoctrination the following may be discerned:

> Consciousness of the engineering fraternity as a functional group in society engaged in constructive work of a common nature, using a common method of thought, and inheriting common obligations.
>
> Appreciation of the heritage of knowledge and art, of standards of performance, and of the traditions of group action for professional development.
>
> Recognition of the confidential relationship between agent and client, of the principle of fair play between colleagues, and also of the encompassing social duty to the public of service adequately and honestly given.
>
> Loyalty to the principles of professional ethics not alone according to the canons in which they have been formulated but also according to the spirit in which they have been conceived.
>
> Obligation to serve the profession in the advancement of its science, technology, and art and also in the discharge of its broad social duty.

To the partial achievement of these ends engineering societies and state registration boards have promulgated standards of qualifications and of conduct. Beyond these, however, there rests the moral obligation upon any great professional group to place excellence above quantitative considerations, loyalty above individual aspirations, and service above personal gain.

Out of such points of view and attitudes will grow pride in belonging to the professional group, devotion to the ideals which it advocates, and acceptance of the obligations it has inherited and recognizes.

Engineers' Council for Professional Development is engaged in a program for the development of such a professional consciousness. Engineering faculties have the chief opportunity to carry this program into effect among engineering students. Through their efforts, with the assistance of the national engineering societies, and the S.P.E.E., substantial progress toward the objectives just stated should be increasingly realized.

Graduate Work

The increasing needs for men of advanced engineering training demand attention in educational planning. These needs are indicated by industry's call for such men and by the increasing emphasis laid upon such training by colleges in their search for engineering teachers. We believe these needs can best be met by the plan already outlined under "Purposes and Problems of Engineering Education" in which the last undergraduate year and one or

more postgraduate years would be planned as a unit. The undergraduate years would lay the foundation of fundamentals in science and engineering, and of a social philosophy, effective expression, and reflective and critical thought, in accordance with the 1940 Report. Graduate study would build further upon this foundation by a rigorous treatment of advanced engineering science. Moreover, our concept of the relationship between undergraduate and graduate work assumes the adoption of the Committee's recommendation * that some of the more advanced technical studies now included in undergraduate curricula be transferred to the post-baccalaureate period.

We recognize, of course, that there are practical factors which will make the wide adoption of the above unit plan a process of evolution. For example, undergraduate work at one institution may not now articulate well with the graduate work at another. Also, students who have taken the *regular* undergraduate program will then decide to go on with graduate study. Thus it will take time to develop the plan, but we urge its development.

The program of graduate work that we envisage involves a transition, begun in undergraduate years, from closely prescribed course work to independent study and research. It will not be pursued by continuation of the customary undergraduate method of specific course requirements. Graduate work of this nature requires teaching ability and leadership of high order as well as first class physical facilities. It cannot be conducted properly where these necessities are lacking. An adequate program of graduate work is costly in comparison with undergraduate work. Many opportunities are afforded in programs of graduate work for close affiliation with basic and industrial research projects. These will lead directly to the production of industrial research workers as well as the highly qualified personnel required in advanced engineering practice.

Another plan of proved effectiveness by which the needs can be met is part-time graduate study by young engineers employed in centers of industry. This is one of the most beneficial developments of engineering education in recent decades. An important fraction of all graduate enrollments in engineering just before the present war was in part-time courses conducted in a few of the larger centers of population. Means were thus afforded for many young engineers to pursue graduate work who could not afford the time or money to do so in full-time programs; they were enabled to round out their education, especially in fields of interest developed in their regular employment.

We believe that the post-war expansion of graduate work should be strongly encouraged wherever well qualified personnel can be assembled. In university centers apart from major industrial communities, the necessary means will include increased numbers of graduate scholarships, assistantships, and fellowships in association with expanded research activities. Institutions in favorable localities should be expected to expand their research activities and programs of advanced training in close coöperation with industries and professional societies. We are convinced that the more complete development of such programs will not only serve the direct interests of

* See page 2 of this Report, also the Report of 1940 on Aims and Scope of Engineering Curricula, page 562, *Jour. Eng. Educ.*, Vol. XXX, No. 7, March, 1940.

industry and the engineering profession, but will also contribute in a marked degree to the fuller realization of a sounder and broader type of undergraduate education, through relieving pressure of time and enabling engineering teachers to find scope for their specialized interests at a more advanced level.

Sub-Professional Technological Education and Training

War conditions have furnished a striking demonstration of the need for technological training of intensive nature, at a level between that of the vocational and secondary schools and that of the engineering colleges. Faced with a critical shortage of technically trained personnel for service in defense industries, the Federal Government established, late in 1940, the Engineering Defense Training Program of the United States Office of Education as a means of supplying this deficiency. Since then, more than 1,500,000 persons have enrolled in the short, intensive courses of this program, which is now called the Engineering, Science, and Management War Training Program. While these courses are of "college grade," as prescribed by the appropriation acts, their chief purpose has been to train assistants and thus to release engineers, scientists, and industrial managers for more important technical and supervisory activities. While the quantitative need for personnel at all levels of technical pursuits is not as great in times of peace as it is in times of war, the *relative* need remains substantially the same, and educational facilities for work at various levels should exist in similar proportions.

The report on the Study of Technical Institutes, published by this Society in 1931, indicated the lack in this country of an adequate system of technological educational programs of intermediate or sub-professional type.

Lack of recognition of such programs on the part of industry, the engineering profession, and the public at large, and of the place they should occupy in the broad field of preparation for technological pursuits is in large measure responsible for this condition. The situation that exists in the United States is unique in this respect among important industrial nations. Not only in the older educational systems of Great Britain and Germany, but also in the newly created system of the Soviet Union, programs of technical training at intermediate levels far outnumber those at collegiate level. It is said that in U.S.S.R., in 1938, there were 3,400 technical institutes of intermediate grade enrolling 700,000 students.* In those countries, therefore, there is a much closer relationship between training facilities and industrial needs than exists in our own country, and much more adequate recognition is given to them than is accorded here. Several independently conducted studies have indicated that from three to six times as many persons are needed as draftsmen, inspectors, laboratory technicians, minor industrial supervisors, and the like than are needed as engineers and industrial managers. These studies have indicated also that the technical needs of many positions in the sub-professional categories can be supplied more appropriately by briefer courses than the four-year college degree program. Yet the relative numbers of individuals trained for subordinate technical positions in this country, in comparison with engineering gradu-

* See "Technological Education in the Soviet Union," by H. G. Tolpin, *Jour. Eng. Educ.*, October, 1943.

ates, are in reverse proportion to the need.

The inevitable result of this situation is to cause industries to seek engineering graduates in large numbers to fill positions for which briefer, less fundamental, and more practical types of training programs would provide more suitable preparation. The result is also to cause many young men to enter engineering colleges who would profit better by pursuing educational programs designed to equip them for more immediate usefulness in the numerous types of industrial pursuits illustrated by the examples given above. The general result of this situation is to cause confusion of aims, purposes, and content throughout the general program of technological education.

We believe that great benefit would result to industry, to the engineering profession, and to engineering education if the condition here referred to could be clarified, and if the aims and purposes of programs at the several levels—secondary schools, vocational schools, technical institutes, and undergraduate and graduate engineering schools—could be more clearly understood and defined than they are at present.

One step that appears to be of primary and immediate importance in this connection, especially because of the impending complications of the post-war years, is the provision of means of formal recognition for institutions offering programs of the technical institute type and for their graduates. At present, neither industries, generally speaking, nor the national engineering societies, nor engineering registration boards, nor federal civil service grant any credit for the educational preparation of graduates of sound institutions operating in this field. Lack of such recognition—or accreditation—caused the provisions of the engineering defense training appropriations to limit the offering of courses to degree conferring colleges at the very time when institutions offering sound programs of technical institute type ought to have been rendering service of great value to the war effort. This anomalous situation should not have existed and it should not recur.

We believe that industry and the engineering profession as well as the schools and colleges should give united support to measures of recognition of sound technical institute programs and of certification of their graduates for a considerable range of technical pursuits. These measures should be similar in general nature, but appropriately different in details and possibly in operation, to those now conducted by Engineers' Council for Professional Development as to engineering colleges, and by state boards of engineering examiners as to individuals. We believe that such measures of recognition and certification would ultimately bring genuine benefit to the colleges of engineering as well as to the technical institutes and their graduates.

Part I. Conclusion

War experiences have altered temporarily the norms of engineering education but have not indicated the desirability of radical changes. With the cessation of hostilities war-time expedients should give place as rapidly as practicable to normal functions and the healthy processes of evolution should be resumed. The directives of the 1940 Report on Aims and Scope of Engineering Curricula remain es-

sentially valid, within their limits. Events have shown one major extension to be needed, namely, a more positive indoctrination in civic and professional responsibilities. It has also become increasingly clear that secondary education needs to be strengthened, especially in mathematics and science, as a means of preparing for collegiate engineering education and means to this end must be sought vigorously.

The bounds of the undergraduate period are set at one limit by secondary education and at the other by certain goals of mastery distinctive to engineering and essential to its professional functions. These goals include mastery of fundamental scientific principles, engineering modes of thought, basic knowledge in some major branch of engineering, elementary competence in the art of engineering application, some understanding of cost relations, skill in the use of English, insights into social relations and processes, and concepts essential to worthy personal and professional life. The goals of advanced knowledge and specialized technique belong properly to graduate and post-college training. The major paths along which progress is to be sought in the undergraduate period include the choice of essential matters and the elimination of non-essential matters of instruction, the grouping of the chosen materials into coherent major sequences, the inculcation of effective habits and standards, skillful combination of teaching methods, the development of creative as well as analytical abilities, and the evaluation of the attainment of the larger goals as well as the details of learning.

Matters relating to administration and management which conform to engineering modes of analysis and procedure have a valid place in engineering education. Trends in industry also make opportune increased attention to the production of industrial materials and of consumer goods, and to the recruitment of the production personnel as distinct from research and planning personnel.

The restoration of graduate work and its extension in scope to include all areas of advanced specialization should be immediate post-war goals. Instruction and research should be developed as complementary and coördinate functions.

The Committee believes that both industry and the engineering profession would benefit from a clearer understanding of the relative functions of technical institutes of intermediate type and engineering colleges, and from the larger development and strengthening of the former. This can be aided by—in fact can scarcely be accomplished without—the establishment of appropriate measures for the recognition of technical institutes by the engineering profession and the acceptance of their graduates by industry and government in a wider range of sub-professional technical occupations.

It is the hope of this committee that one of the chief results of this report will be the stimulation of educational experimentation among engineering colleges and the presentation of papers before regional and national meetings of this Society on specific measures for accomplishing the purposes indicated herein. The immediate post-war period, when readjustments must be made in any case, would seem to be an opportune time for the trial of new methods and for the dissemination of information about them.

PART II

MATTERS OF IMMEDIATE CONCERN

As has been stated earlier in this report, all education is at present in a state of flux. It is appropriate, therefore, to reëvaluate engineering education in the light of the new conditions that surround it. Opportunity is afforded to compare conventional educational programs with those of unusual pattern and great variety that the colleges are now conducting. In the same institution, under the same administrative control, and with the same faculty, there are now in progress, in many cases, regular engineering curricula for civilian students, the Army Specialized Training Program, the Navy College Training Program, other special courses for the military services, special full-time training programs conducted for war industries, and the courses of the Engineering, Science, and Management War Training Program. Out of this complex situation certain facts emerge and certain lessons may be learned. It is clear also that difficult problems lie ahead for which solutions must be found as soon as possible; and it is also clear that the solution of some problems must await removal of uncertainties due to war and actions of government.

Secondary School Preparation for Engineering.—Evidence is appearing to support the belief previously held but based upon only partial proof, that secondary school education unless specially planned is generally inadequate as preparation for collegiate engineering education. By means of the qualification tests of the Army and Navy college training programs students possessing high scholastic aptitude have been selected; yet poor preparation, especially in mathematics and science, has caused the failure of large numbers of the students of top ranking ability among high school graduates. The results of these tests are also indicating wide variation in the quality of secondary school preparation in various parts of the country. More complete study of the results of a series of these nation-wide examinations taken in each case by several hundred thousand candidates will provide the basis on which high school administrators and teachers and members of engineering college faculties should be able to coördinate their programs and close the gap that has too long existed between secondary and collegiate education.

We suggest, therefore, that the appropriate agency of this Society present the data derived from the Army and Navy qualification tests to state departments of public instruction, to associations of high school principals and public school superintendents, and to teacher and parent-teacher organizations with all the emphasis that the importance and accuracy of this material warrant.

Selectivity in Admission of Students.—At the same time, evidence of the war training programs indicates plainly that the practice of indiscriminate admission of students wherever it obtains should be abandoned in favor of one of greater selectivity. More valid measures of scholastic attainment and aptitude are now being developed. They should be used as soon as they are ready. This Society, Engineers' Council for Professional Development, and the Carnegie Foundation for the Advancement of Teaching are actively engaged in this

undertaking. This movement should be supported vigorously by the engineering profession as well as by the engineering schools themselves.

Junior College Preparation for Engineering.—Growth in numbers of students transferring from junior colleges to engineering colleges points to the desirability of closer coördination of the programs of the two than now exists. Experience indicates that in some instances the present lack of coördination is due to lack of knowledge of the requirements of engineering curricula. It would seem advisable for Engineers' Council for Professional Development and this Society to coöperate more effectively with junior colleges, looking to improvement in the preparation of candidates for admission in advanced standing, in an undertaking similar to that now in progress to insure the admission of better qualified entrants from the secondary schools.

Scholastic Ability vs. Financial Resources.—One feature of the Army and Navy programs should be widely adopted in times of peace if means of doing so can be found; namely, the admission of students on the basis of mental capacity (a national resource that should not be wasted), scholastic preparation, and physical fitness without regard to the immediate ability of the student and his family to meet the expenses of a college education. This democratic process is one of the best things that has come out of the war situation and it should be continued. Means of doing so are not as readily discerned as is the desirability of the end sought. We would suggest the adoption of one principle in this connection, namely that the student, who is the one most directly benefited, should share in the expense of his own education. Since in many instances he will not be able to earn all of these expenses, it would be desirable to establish a system of loans, in addition to present loans financed by the institutions, with local, state, or federal government supplying the capital, to be repaid from the increased earning power resulting from higher education.

If means can be found to institute this procedure, we believe it should be utilized to insure the admission of better qualified students, not as a means of inflating college enrollments.

Physical Conditioning of Students.—We have been impressed with the results of more adequate physical conditioning of trainees provided in the Army and Navy programs. This points to the desirability of a reëxamination of collegiate physical training programs in times of peace.

Intensive Programs.—It is possible that the retention in the post-war period of intensive programs of engineering study directed toward specific technical objectives, such as those of the E.S.M.W.T. programs, may be advocated by some as a continuing responsibility of professional schools of engineering. While fully supporting the offering of such programs under the exigencies of war, we believe that it would be unwise to continue many of them on the campus as the normal programs of engineering colleges in times of peace. Such intensive courses of specific aim as should have a permanent place in technological education belong, we believe, in the technical institute field as referred to previously in this report.

Education of Veterans and War Industry Workers.—The flow of returning veterans to the engineering schools has begun. It is probable that Federal legislation will provide for the support of the better qualified of these veterans

through a sufficient period to complete their engineering education. For purposes of readmission procedures, returning veterans may be classified in four groups.

1. Those who will resume their curriculum at the point of interruption without the need of any special process of adjustment, and those who will enter regularly as freshmen.
2. High school graduates who have not attended college but have pursued part or all of a war training program at college level, such as the Army Specialized Training Program.
3. Former engineering college students who have pursued all or a part of a military training program and desire to reënter in higher standing than at the point where their civilian program was interrupted.
4. Former college or high school students who wish to complete their education by pursuing an abbreviated program either on a full-time or a part-time basis in order to become financially independent as quickly as possible.

The first group will present no problem. For groups 2 and 3 the problem will be essentially the same, that is, of supplementing the schedule of courses of the military training program so as to get the students in step in regular engineering curricula as quickly as possible. Many of these cases will require individual treatment. It may be necessary to admit veterans at times other than the beginning of a semester or term. An "adjustment term" has been suggested as an expedient to meet this difficulty. One such plan, already adopted, is to arrange special courses each to be pursued intensively for a four-week period. This will permit the returning veteran to reënter college at the beginning of any four-week period and to resume regular work at the beginning of the next following semester with some of his irregularities adjusted. Such a plan, obviously, can be conducted only in institutions having faculty groups large enough to absorb the additional teaching load. The chief difficulty in the adjustment process will probably be to complete adequate foundations in mathematics and science for the pursuit of professional engineering courses, as well as to round out incomplete work in English and the humanities. While the colleges will desire to deal with these students liberally by reason of the sacrifices they have made for the sake of the national safety, they will not wish to jeopardize the interests of the students themselves by providing programs of subnormal quality for them. It would seem wise, therefore, to follow the policy of providing programs that will meet the general educational objectives of a standard undergraduate curriculum without insisting upon minute details of course to course equivalence.

For the transitional period it may be desirable to continue year-round calendars in order to complete the process of readjustment quickly. It may also be advisable in some instances to provide separate class sections for veterans whose education has been interrupted for long periods instead of placing them in the same classes with less mature students who have progressed with less interruption.

Returning veterans and displaced war industry workers who desire to resume normal civilian pursuits more quickly than is possible in regular programs may desire to pursue short intensive courses having specific vocational aims either on a full-time or a part-time basis. Many engineering colleges that have participated in the war training programs of the United States Office of Education (E.S.M.W.T.) may feel obligated to continue work of this type in the early post-war years.

Those which have extension divisions or evening sessions can do so with only the difficulties incident to a peak load such as has been carried during the war period. Other institutions may find it necessary to ration their facilities under the anticipated combination of a resumption of normal undergraduate and postgraduate work, programs for returning veterans, and the offering of courses of the E.S.M.W.T. type. No formula can be written as a guide to the solution of this difficulty.

Educational Guidance of Veterans.—A period of time will elapse for members of the armed forces between the termination of the more active phases of military duty and actual demobilization. In some instances this period will be spent in recovery from physical or mental injuries. It may occur either before or after the armistice. Under whatever conditions or at whatever time this interval will be spent, provision should be made to assist and advise veterans in making their individual plans for resumption of interrupted educational programs. This Society and individual engineering colleges should offer coöperation to whatever authorized agency is charged with the responsibility for guidance and assistance.

When the period awaiting demobilization is long, refresher courses may be offered by the armed forces to facilitate the transition from military to civilian life, to utilize profitably the mental energy of veterans in preparation for resumption of engineering study, and to maintain morale. Engineering educators should keep themselves informed of such measures as these in order to coördinate their own programs of instruction with them and thus better to aid veterans to adjust themselves to renewed engineering study and to minimize the lost period of productive civilian pursuits.

Universal Military Service.—Legislation providing for universal military service in the post-war years is now under consideration. Whatever the provisions of such legislation may be it seems clear that if adopted they will have important effects on higher educational programs. If young men are required to devote a full year to uninterrupted military training as soon as they reach a designated age or when they graduate from high school, the effect will be to defer entry to college correspondingly. The possible disadvantage of discontinuity of schooling resulting from such a plan may be offset by increased maturity and better disciplined attitude toward work and study. If military duty may be performed in several shorter periods of duty, such as three or four months during each of several successive years, the result may be strongly to influence the colleges to adopt a four-term or three-semester calendar. Furthermore, if military procedures are such that quotas of students are called up for duty in each three-month or four-month period, the effect may be to cause continuation of a year-round academic calendar. Obviously, either of these procedures would have important effects on the possibilities of vacation employment by students in industry.

If universal military service is operated on the plan of a full year of duty performed in one continuous period, the resulting deferment of admission to college may cause some students to desire to follow some form of accelerated program in order to graduate as quickly as possible.

Army and Navy R.O.T.C. programs may also be affected by universal military service, but the details of legisla-

tion will have to be awaited before these effects will be known.

While it is possible at present only to conjecture about the foregoing contingencies, they must be kept in mind as possibilities in connection with post-war planning.

The Accelerated Program.—If military conditions are such as to allow freedom of choice as to the type of calendar to be adopted after the war, there will doubtless be discussion of the desirability of continuing the present type of accelerated program. We believe that the following considerations will be recognized as outweighing the advantages of the accelerated program under normal circumstances:

1. Difference in maturity of graduates of the program of four calendar years as contrasted with those of the accelerated program of shorter duration.
2. The value of vacation periods spent in acquiring industrial experience as well as the maturing influences which result from contact with engineers and industrial workers in practice.*
3. The value to faculty members of periodic opportunities for industrial experience, for full-time research, for writing, or for other broadening pursuits as well as the mental stimulus that comes from periodic change of occupation.

Academic Credit for Military Programs.—For recommendations relating to policies in this matter the reader is referred to the report of the committee of the Society for the Promotion of Engineering Education on "Credits for In-Service Study." †

More specific information concerning the educational work done under the auspices of the armed forces will be found in the handbook to be published by the American Council on Education.

Rehabilitation of Faculties.—The effects of the war on engineering faculties may be epitomized as a growing need of rehabilitation. The longer the duration of the emergency, the more acute the cumulative situation becomes. The normal recruitment and development of able young teachers to fit them to fill important posts has been replaced by appointments based on expediency. This leads to the danger of permanent retention of the poorly qualified. Many of the ablest teachers in the younger and middle-age groups have entered the armed services, war research, or highly paid industrial positions. Some of these will return with the asset of valuable experience acquired; others have been lost permanently, including those who will remain in our enlarged military establishments. Some who return to their college posts may find them less challenging than the positions they have occupied in the Army and Navy and war industries. These latter groups include many whose vigor and ability qualify them to become the future key men in engineering faculties. Great care must be exercised to assist these men to readjust themselves to the conditions of academic work and to give them opportunities for the exercise of their enlarged abilities. Other key men will have to be replaced. Faculty groups as a whole will need a period of rest and recuperation from the long grind of continuous work under heavy overload.

No more serious problem could confront the engineering schools than that of post-war faculty rehabilitation. No simple or quick process of solution can be discerned for it. We can merely

* The values of periods of industrial employment for undergraduate students as here stated are provided systematically for students of coöperative engineering curricula.

† Published in the *Journal of Engineering Education,* November, 1943.

state some aspects of the problem and sound the caution that the greatest possible care and patience should be exercised in attacking it so as to adhere to the high standards of faculty selection and upbuilding that the interests of engineering education require.

Part II. Conclusion

Each of the matters discussed in the preceding paragraphs is of individual importance and will demand attention in the post-war years. In the aggregate they will have an important bearing on the course that engineering education will follow for many years. Two problems stand out as of great importance: (1) Devising more valid means than have been employed in the past for selecting and admitting students and insuring better preparation in secondary schools, and (2) building up faculties not only to the pre-war level of effectiveness but well above that level. Engineering education can never advance beyond the qualifications of its students and teachers. Hence, the engineering profession, industry, and the public who have a vital interest in its welfare, should vigorously support every possible means of improving the quality of its personnel.

Of more immediate concern is the planning of appropriate educational programs for returning veterans in order to permit them to enter productive pursuits in the minimum time consistent with sound practice. This can and will be done. We would call attention especially in this connection to provision of postgraduate work, either full-time or part-time, for those who desire and can profit by it.

If, as present indications seem to suggest, there is to be a reaction away from the war-time accelerated academic calendar and if conditions of universal military service are such as to permit freedom of choice in relation to this matter, it may be necessary to meet the criticism of those who see serious waste in permitting valuable educational facilities to be operated for less than a full calendar year. We have referred previously to the values derived by students from the experience and the maturing influence of employment in industry. Engineering colleges might well establish systematic means of aiding students to secure employment that will afford the right sort of experience,* and of requiring such experience as a prerequisite to graduation. If educational programs are to be in regular operation for less than the full calendar year, it is equally important that vacations be used profitably by teachers. It seems appropriate, and even necessary, that they be expected to spend vacations in industrial employment, research, writing, or other pursuits that will keep them abreast of current developments in science and engineering or otherwise promote their professional advancement.

Finally, and of the utmost importance during post-war years, will be the inevitable problems of financing higher education during a period of world-wide economic rehabilitation. One not inconsiderable aspect of this matter will be the necessity of restoring to normal efficiency laboratory facilities worn out or damaged by war usage. The war has caused a suspension of replacement of items of equipment that have become obsolete; others have undergone abnormal wear and deterioration; provision must be made to make good these deficiencies. In sum, a period of serious financial difficulty lies ahead.

Wide fluctuations in enrollment of

* Certain colleges achieve this result through the coöperative plan.

engineering students are being experienced. These fluctuations occur not only in total numbers but in distribution by years and curricula. It is to be anticipated that this condition will continue into the post-war period. It is possible also that in the immediate post-armistice years there will be a considerable influx of new students at the same time that veterans are returning to complete their curricula. How long this condition will continue is a matter of conjecture, but it seems plain that the resulting problems will be severe in the internal administration of engineering colleges.

If at the same time there is to be a permanent increase in enrollment in science and engineering, and if colleges of engineering are to occupy a larger place and exercise a more general function than they do at present in the scheme of collegiate education in this country, it is not only appropriate but necessary to plan in advance for the facilities and staffs which these changes will require. And it is especially important that the educational problems that will accompany such an expansion of scope and function should be considered on broad lines in the interest not only of industry and the engineering profession but of the nation as a whole.

The Pre-Engineering Inventory

By K. W. VAUGHN

Director, Measurement and Guidance Project in Engineering Education

Basic Considerations

During the past thirty years, educators and psychologists have studied the possibilities and limitations of various objective tests suitable for selecting engineering students. Numerous projects and researches into this important problem have been conducted with varying degrees of success. While many of these researches have produced significant results, the fact remains that we have only begun to discover the possibilities inherent in the intelligent application of batteries of tests for purposes of selecting and guiding beginning engineering students.

When the Measurement and Guidance Project in Engineering Education was established by the S.P.E.E. and the E.C.P.D., the Advisory Council of the Project made provisions for definitive studies of various types of selection and guidance tests. It was recognized in the beginning that there were then in existence a number of tests which could be utilized for this purpose. The problem resolved itself therefore into the question of whether we should attempt to assemble a battery of commercially available tests or develop a new battery of tests for this particular purpose. We chose the latter course for several reasons, among which three are particularly important. In the first place, while there were several "engineering aptitude" tests or batteries available commercially, none of these tests met all of the specifications deemed important by the Advisory Council. Furthermore, it would not have been possible for the Project to revise and refine tests copyrighted by a commercial or service agency. Finally, the most appropriate and valid tests then in existence were not available in the form of an integrated test battery. It would have been very difficult to assemble from several sources a battery of tests which would prove administratively practicable. Tests developed by different groups or agencies frequently vary in standards of internal perfection and methods of reporting student performance, and consequently, the results derived from such tests are generally not comparable. Our plans called for the development of a test battery yielding scores and norms which would be not only very dependable in themselves but highly comparable from test to test within the battery. In view of these facts, it appeared more feasible to develop an entirely new battery of tests than to use tests developed by others.

Before a test battery designed to measure a high-school graduate's potentiality for the study of engineering could be devised, it was necessary for us to offer a tentative answer to a very fundamental question. This question has been asked in a number of ways,

but its significance is very much the same in whichever form it appears. It has been asked as: "Who should become an engineering student?"; "What should the beginning engineering student know?"; "What are the educational prerequisites of the engineering curriculum?"; or in another vein, "What is engineering aptitude?"; "Who has engineering aptitude?"; "What are the desirable qualities of an engineering student?"; *ad infinitum*. Unfortunately for our purpose, no conclusive answer to any of these questions has as yet been obtained. We were assisted, however, by a voluminous literature on the subject, the previous researches and experience of the S.P.E.E. and E.C.P.D. Committees on Student Selection and Guidance, and researches conducted under the sponsorship of the Carnegie Foundation for the Advancement of Teaching. Thus, while we were not able to formulate a well-defined concept of "engineering aptitude," we were able to proceed in an operational manner, basing our procedures on the objective evidence available in the literature of achievement and aptitude testing and our own experience with the problem.

Briefly stated, our problem was to devise a battery of tests which would be valuable for predicting success in the basic or pre-specialization phase of the engineering curriculum. The largest proportion of failures in engineering colleges generally occurs during the first two years. Assuming that we can discover abilities and qualities related to success during this period and are able to devise dependable tests of these potentialities, it should be possible to reduce student mortality by earlier and more effective guidance of certain types of students who would profit more by transferring to other college curricula.

Our point of departure can be justified as far as the engineering educator is concerned. It can be reasoned that before a man becomes a professional engineer, he must normally have completed four years of formal college training. It is obvious that young men who cannot successfully complete this prerequisite of professional licensing are generally denied professional status. It does not follow, however, that all "good engineers" are necessarily trained in colleges, but such is now becoming the rule. The increasing complexity of technical knowledge further suggests that the engineers of the future will face an increasing number of situations in which intensive study and practical application go hand in hand. In such cases a thorough training will be invaluable.

We have said that the student is required to demonstrate his ability to succeed in the early phases of the engineering curriculum or he is eliminated via the failure route. The engineering curriculum includes "stiff" subjects: college mathematics, one of the most highly selective of all fields of study; descriptive geometry and engineering drawing; chemistry and physics; and certain pre-professional subjects, *e.g.*, surveying and mechanics. Whatever engineering aptitude may be, it most certainly includes the ability to complete successfully these required subjects, and as compared with many other college subjects, they are difficult for the average student. There is no question that such factors as persistence, application, interest, motivation, and many others such as financial troubles play their parts in the case of individual students. In the absence of

certain specialized abilities, however, the student is doomed to failure no matter how persistent, hard-working, or interested he may be. We know, for example, that certain types of students are unusually poor thinkers in the abstract symbolism of mathematics. These students generally experience the greatest difficulty in engineering for much of the thinking in engineering study is mathematical in character. Other students do not readily comprehend scientific, mathematical, or technical materials, and while such students may not fail scientific or technical courses, they are called upon to exert greater efforts over a longer period of time. Many are not willing to make such efforts.

Instruction in the college of engineering begins at a certain level and it is assumed that students admitted to the college are capable of undertaking work at that level. To insure that students can undertake the prescribed work, the college admission requirements generally specify the successful completion of certain high-school courses, particularly mathematics and science. Most colleges have long since discovered, however, that such regulations are not sufficiently selective in character to prevent student failures. In setting up such regulations, educators recognize that there are definite prerequisites to engineering study and that students must become proficient in certain subject areas before they can successfully undertake engineering study. These prerequisites suggest a method for studying students' ability to begin engineering study. By measuring the student's mastery of the prerequisites of engineering study, we can secure an estimate of whether or not he can succeed in its initial phases.

It has been the experience of educators that one of the best bases for estimating a student's success in an advanced course is the student's success in an elementary course. If the student has had unusually high grades in elementary algebra, our best guess, in the absence of other information about the student, is that he will do well in the advanced algebra course. If, on the other hand, he has experienced considerable difficulty in elementary algebra, there is little reason to assume, again in the absence of other information about the student, that he will become one of the best students in the class in advanced algebra. Past achievement in a subject field, therefore, is a good predictor of future success in the same subject field.

The foregoing paragraph seems to imply that achievement examinations are the best predictors of success in the engineering curriculum, at least for certain aspects of that curriculum. In many instances this has proved true, but in others, the achievement test has evidenced considerable limitations when used for this purpose. Achievement tests in mathematics, for example, have proved very helpful in estimating a student's chances of success in engineering, but achievement tests in physical science have proved considerably less valuable.*

The use of traditional achievement examinations as college entrance tests would be a more satisfactory procedure if the content and objectives of high-school courses were fairly uniform in character. It has been irrefutably demonstrated, however, that high-school courses vary tremendously in emphasis, content, and the degree of

* See I. L. Kandel, *Professional Aptitude Tests in Medicine, Law, and Engineering,* Bureau of Publications, Teachers College, Columbia University, New York, pp. 61–78.

mastery required. This lack of uniformity of content and instruction, democratic and stimulating as it is, nevertheless creates problems for the college admissions officer who is faced with the necessity for evaluating the educational development of students from a large number of high schools. It is very difficult to devise achievement examinations measuring students' knowledge of units of instruction and obtain examinations which apply equally well to students graduated from a large number of high schools. This fact has encouraged the development of improved types of achievement examinations which reduce the effects of variability of content and instructional emphasis in high-school subjects.*

Most achievement examinations are deficient in another important respect—they fail to reveal learning which has taken place outside the school. In restricting their scope to the effects of formal instruction, they derive no information about abilities not developed by formal study. Someone has said that many students educate themselves, not because of the schools, but in spite of them. Colleges of engineering cannot afford to reject a good candidate who has prepared himself at home, in his workshop, or on a job, and take in his place a candidate who has met the formal academic prerequisites but who lacks fitness for engineering study.

There are a number of approaches to measuring the components of potentiality for an activity, work, or profession. In our case, one possibility was to construct examinations measuring achievement in those high-school subjects or subject fields which are generally regarded as prerequisites to engineering education. Had we taken this approach, our test results would have been expressed in terms of the student's achievement in high-school mathematics, physics, chemistry, English, and certain other subjects. A second possibility was to devise tests measuring the various mental processes or factors involved in engineering study. Had we adopted this approach, the test results would have been expressed in such terms as inductive thinking, deductive thinking, symbolic language, judgment, and critical thinking. A third possibility was to devise tests measuring abilities important in engineering study and to describe these abilities in operational terms without attempting to identify the various mental processes involved in the ability. In this approach, test results are expressed in such terms as the ability to solve certain types of problems, ability to recognize the meanings of certain types of words, ability to read and comprehend materials of a particular kind, and ability to comprehend and apply certain principles.

Fortunately for our purposes, we were not committed to the exclusive use of any of these three approaches. Our approaches and procedures are determined on the basis of individual tests, depending upon what each test is intended to measure. The tests in the current form of the test battery utilize more than one approach to measurement. In one sense, the individual tests in the battery are achievement tests for they evaluate educational achievement in certain high-school fields of study; in another sense, they are aptitude tests for they measure abilities which are not necessarily re-

* Good examples of this type of improved achievement examination are the Iowa Tests of General Educational Development, the Armed Forces Institute Tests of General Educational Development, and the Coöperative General Achievement Tests.

stricted to a particular field of study. The tests are organized according to abilities rather than subject fields, and the results are reported in operational terms rather than in terms of the mental processes involved.

The initial step in developing the test battery was accomplished by the author before the Measurement and Guidance Project was instituted. This step consisted of a careful analysis of the educational programs of more than 100 accredited colleges of engineering. The freshman program was the object of special studies in which the content of individual courses, units of instruction, and widely-used textbooks were carefully analyzed and categorized. The purpose of this study was to provide a basis for estimating what the engineering student is expected to have accomplished before he enters the college of engineering, and what he is expected to accomplish during the first year of study. By taking an inventory of all those abilities, knowledges, skills, and proficiencies which the student presumably has acquired before he begins engineering study, we were able to establish a frame of reference to guide us in the development of the test battery.

In the experimental stages, we were more concerned with determining the abilities or achievements which should be measured by the battery than we were with developing new techniques for measuring these abilities. It should not be inferred, however, that we underestimate the importance of refined techniques of questioning and item writing. In fact, once we have identified the important abilities and aptitudes which should be tested, our greatest opportunities will lie in the improvement of present techniques and the discovery of new techniques for measuring these potentialities of the engineering student.

A battery of tests is a sort of inventory presenting categorized lists of items a student should know or be able to do. In this sense, the educational or psychological test is analogous to the business inventory which is used in the evaluation of stocks or supplies on hand. In the smallest firms, every article of merchandise is examined and evaluated before it is listed in the inventory; in large firms, however, goods and merchandise are counted in lots or types and only a *sample* of each type of goods is examined. To examine the contents of each carton in a large warehouse would prove too expensive and time-consuming to justify the added effort over that involved in examining selected samples of the goods. Similarly, in educational and psychological measurement it is not necessary to measure all of the student's "equipment," *i.e.*, his knowledge or abilities, provided the sampling procedures employed dependably account for the important aspects being measured. Administering the test battery to a freshman is analogous to auditing his "educational development" account. The student's high-school credentials may state that he has successfully completed three years of mathematics; the mathematics test in the battery "checks" to ascertain whether the account is active and whether the assets are "cash" or merely "paper profits."

Since this particular test battery is an inventory of the abilities and knowledges that a freshman engineering student is assumed to have acquired before he undertakes engineering study, the battery was entitled the *Pre-Engineering Inventory.* The *Inventory* includes tests of those particular scholastic abilities which are assumed to be

important to the success of the beginning engineering student. Our present studies are concerned with determining those particular scholastic abilities which should be measured and discovering the relative weights which should be assigned to each ability in evaluating the student's promise for engineering. When these studies are complete, we can extend the *Inventory* to include measures of non-intellectual characteristics of the individual, *e.g.*, interests, personality, and adjustment, and study these in turn. By continued experimentation, we can evolve a battery of tests which will reliably inventory the intangible complex referred to as "aptitude for engineering."

The Criteria

In developing the *Pre-Engineering Inventory*, the Project is guided by a number of practical and technical criteria. Some of these criteria are general test-construction policies while others serve as standards for evaluating the test battery as it evolves through its successive stages of development. Eight of the most important of these criteria are listed below, and, following each criterion, an attempt is made to explain why it must be considered in the development of the *Inventory*.

Criterion No. I—Each test in the battery must measure an ability known to be important in engineering study

The six tests included in the current form of the *Pre-Engineering Inventory* measure the following abilities:

1. *General verbal ability*—The ability to comprehend the meaning of words in the vocabulary of general reading.

2. *Technical verbal ability*—The ability to comprehend the meaning of important words in the vocabulary of high-school science and mathematics.

3. *Ability to comprehend scientific materials*—The ability to comprehend reading materials similar to those encountered in college science, engineering, and mathematics.

4. *Ability to do quantitative thinking*—The ability to solve problems ranging in difficulty from arithmetic to the elements of analytic geometry, to comprehend passages involving quantitative concepts, to interpret graphs and tables and to apply mathematical thinking to the solution of new problem types.

5. *Ability to comprehend mechanical principles*—The ability to comprehend and apply physical principles and to solve problems involving direction of motion, mechanical advantage, forces, and other mechanical principles.

6. *Spatial visualizing ability*—The ability to visualize form and detail from plane figures.

All of the above abilities are known to be related to success in engineering study. While we cannot conclusively assign their relative importance in predicting success in the engineering curriculum, we can justify their inclusion in the *Inventory* on the basis that they are components of the particular type of scholastic ability characteristic of the successful engineering student. We do not contend, however, that these are the only abilities which should be tested by the *Inventory*. Tests of these abilities were arbitrarily chosen for study on the basis of previous researches into the effectiveness of tests for predicting success in the engineering curriculum. Our studies may reveal that some of the tests in the *Inventory* should be replaced by tests of other abilities or traits. Before a test is discarded, however, it is perfected and given an extended opportunity to

demonstrate its merits. Test validities are studied over a two-year period, and if, at the end of that period, an individual test has failed to make a contribution to the validity of the battery, it is replaced by a more valid test which was being studied and perfected during the same period.

Criterion No. II—Each test in the battery should have guidance values

The *Pre-Engineering Inventory* is an entrance examination serving a special purpose. Scores derived from the battery provide a basis for comparing the freshman engineering student with the other members of his class and with freshman engineering students in general. These scores can be used to estimate within broad limits the individual's chances of success in the engineering curriculum, but the battery makes no provision for evaluating fitness for study in college curricula other than engineering. The guidance functions of the battery are, therefore, specialized in character, and pertain only to students applying for admission to the college of engineering.

The use of test scores in the guidance of students is greatly facilitated by reporting easily interpreted scores which have meaning for the counselor and the student. The student's performance on the battery is reported in the form of a test profile showing his percentile standing with respect to his own class and also with respect to all students enrolled in the coöperating institutions. The test titles are meaningful for counselors, but students frequently forget the exact nature of a particular test. To assist the student in interpreting his own test profile, the meanings of the test scores are listed on the reverse side of the profile.

Criterion No. III—Each of the tests in the battery should meet the technical standards of a superior test

The tests in the *Pre-Engineering Inventory* are required to meet very high technical standards. Individual tests are revised and refined until the reliabilities of the test scores become approximately .95 or higher for typical groups. Such scores are dependable enough to be used in the guidance of individual students. The test battery as a whole is required to maintain a reliability of .98.

In refining the several tests, each item is required to meet rigorous standards in order that maximum reliability can be secured with minimum test length. Each item is required to discriminate effectively between students scoring highest on the tests and those scoring lowest on the tests. In evaluating the item, performance on the individual test is accepted as the criterion, rather than performance on the total battery. By following this procedure, one or more tests can be added to or dropped from the battery without affecting the validities of the items in the remaining tests in the battery.

The validity of the *Inventory* as a whole depends upon the relationship between the composite score and various measures of success in the engineering curriculum. These validities will be a direct measure of the effectiveness of the battery for predicting student success in engineering study. Our central problem is to refine, adjust, and perfect the battery until we reach a limit beyond which it is impractical to attempt to secure greater validity. We already have definite evidence that the *Inventory* is a highly valid instrument as compared with

other test batteries used in selecting engineering students. In controlled studies involving more than 800 students in two colleges, the validity coefficient for the Pre-Engineering Inventory was .67 in each case. Seven of the most widely-used classification tests were also administered to the same groups for purposes of comparison. The validity coefficients for these tests ranged from .33 to .63.* These validity coefficients are the correlations between scores on the tests and first-term grade-point averages.

Criterion No. IV—Each test in the battery should be of suitable difficulty

This criterion might well have been included in the discussion of the technical standards of a superior test. It is treated as a separate criterion because of its significance in designing the *Inventory*.

The difficulty of a test determines to a very large extent its usefulness for a particular purpose. Most college entrance examinations are designed for the average college freshman irrespective of the area of study he expects to undertake. One of the most striking findings in the early experimentation was the discovery that mathematics and science tests adjusted to the abilities of engineering freshmen are much too difficult for college freshmen in general. On the other hand, tests of intelligence and general verbal ability apply about equally well to freshman students electing various curricula. By adjusting the difficulty of the *Inventory* to the abilities of beginning engineering students, we have devised tests which would have serious limitations if applied to college freshmen in general.

Critics asked to review the *Pre-Engineering Inventory* tests frequently commented to the effect that the tests were too difficult. Our experimental data indicate, however, that the tests in the current forms are satisfactorily adjusted to the abilities of the freshman students in the coöperating institutions. Any question which is correctly answered by less than 15 per cent or more than 85 per cent of all students taking the test is not retained. Had we applied this principle and standardized the examinations on a population of liberal arts freshmen rather than engineering freshmen, certain of the tests would have been decidedly less difficult, and also generally less satisfactory for measuring the abilities of engineering students.

Criterion No. V—Each test in the battery should contain questions sampled in a manner which insures the appropriateness of the tests for students about to begin the study of engineering

The sampling of questions or items presented in a test has considerable influence on its reliability and validity. The questions presented in the *Pre-Engineering Inventory* are based on a preliminary analysis of the content of the freshman engineering curriculum. Using this analysis as a guide, it was possible to devise questions which measure various aspects of the several abilities being tested. All of the tests are composed of questions which have a direct bearing on the content typical of the first year of the engineering program.

* Summaries of these unpublished studies can be obtained from the Engineering Project Office, 437 West 59th St., New York 19, New York.

Criterion No. VI—The test battery should emphasize the permanent results of learning rather than the memory of facts and details

One of the principal shortcomings of most achievement examinations is the heavy emphasis upon factual information. The *Inventory* places greatest emphasis upon the student's ability to use information in answering questions or solving problems, to apply principles which are stated for the student, to discover principles when data are supplied, and to interrelate pertinent items of information. In all, not more than 20 per cent of the total working time is devoted to the measurement of abilities depending primarily on memory. The remainder of the working time is devoted to measuring the student's ability to apply his knowledge in a realistic and meaningful way.

Criterion No. VII—The test battery should include provisions wherever possible for evaluating out-of-school experiences as well as the results of formal learning

Out-of-school activities are frequently a good index of student interests. If a student has a workshop, scientific hobbies, or reads scientific magazines, he will unquestionably acquire information, skills, and attitudes, some of which may be helpful in his study of engineering. This aspect of the student's educational development is difficult to identify and to measure. We would be first to admit that at this time the *Inventory* does not measure these accomplishments as satisfactorily as is desired. The Project Office is at present studying interest and hobby questionnaires obtained from more than 1,000 beginning engineering students. These studies should result in the development of suitable methods for evaluating certain out-of-school experiences.

Criterion No. VIII—The test battery should be suitable for use in a large-scale program

The nature of the problem dictates that the Project tests and procedures be validated in a number of representative colleges of engineering. Test validities are known to vary from institution to institution, depending upon factors within the institution. At present, eleven colleges of engineering are participating in the Project.

The test battery is organized in such a manner that it can be administered under a variety of conditions with a minimum of effort on the part of the examiners. The tests are contained in two booklets, one booklet for each of the two testing periods. Machine-scorable answer sheets are employed and all of the scoring and reporting is done by the Project Office.

The Pre-Engineering Inventory Revised Form A

The experimentation with the tests in the *Inventory* extends over the period of the past two years. The battery has progressed through two major revisions in which the individual tests and items were revised and improved. The reliabilities of the tests as well as their validities have been successively increased so that at least four of the six tests can now be assumed to be in final form. We have sufficient evidence to indicate that *Test I—General Verbal Ability, Test II—Technical Verbal Ability, Test III—Ability to Comprehend Scientific Materials,* and *Test IV—Ability to Do*

Quantitative Thinking deserve a permanent place in the battery. *Test V—Ability to Comprehend Mechanical Principles* and *Test VI—Spatial Visualizing Ability* will be very carefully studied during the next year. The test of ability to comprehend mechanical principles has a relatively low validity for predicting success in the early stages of engineering study, but we expect this validity to increase sharply when the student undertakes the study of physics, which normally occurs in the sophomore year. We are fairly sure that a test of visualizing ability should be included in the *Pre-Engineering Inventory*, but we are not as yet satisfied with our present techniques of measurement. During the coming year, we expect to make an extensive study of a number of spatial tests and improve the techniques now employed in the *Inventory*.

The *Pre-Engineering Inventory, Revised Form A*, will include a seventh test. This is a test of the ability to understand social science terms and concepts and to comprehend reading materials in the social sciences. This test may or may not have validity for predicting success in the engineering curriculum, but there is little question that the student engineer should be aware of political and economic factors influencing our national life. Engineers play a very important part in our technological advances. If we cannot justify the inclusion of the social science test on the basis of its validity for predicting success in the college of engineering, we can at least justify it on the basis that engineers as citizens and voters should be keenly aware of the social forces operating in our democracy.

Revised Form A of the *Pre-Engineering Inventory* will be available for use on or about June 1. This form requires six hours to administer, of which five hours and forty minutes represent actual working time for the student. The battery is designed to be administered in two three-hour periods which may be scheduled on the same day. The tests administered at one session are contained in a booklet which simplifies the problem of distributing and collecting the tests. The time allotted to each test is as follows:

	Minutes
Information Blanks and Interest-Hobby Questionnaire	20
Test I —General Verbal Ability	35
Test II —Technical Verbal Ability	25
Test III —Ability to Comprehend Scientific Materials	90
Test IV —Ability to Do Quantitative Thinking	70
Test V —Ability to Comprehend Mechanical Principles	40
Test VI —Spatial Visualizing Ability	30
Test VII—Ability to Comprehend Social Science Materials	40

Implications

At this time when there are so few students enrolled in engineering colleges, when the problems of selection are practically nonexistent, and when our energies are devoted to winning the war, we may fail to anticipate the postwar problems with which engineering colleges will be confronted. In the postwar period the problem of student selection will probably become the most acute in the history of engineering education. Thousands of students formerly enrolled in the basic engineering curriculum of the A.S.T.P., the backlog of students normally electing engineering, and the regular high-school graduating classes will probably create abnormally large enrollments in engineering colleges. The

administrator, the counselor, and the teacher will need dependable measures of student ability to guide them in the assignment and guidance of individual students in the postwar years.

It is extremely fortunate that most of the researches underlying the *Pre-Engineering Inventory* were conducted before student populations were decimated. Researches conducted under present conditions will apply only partially to normal student populations. The difficulty of the tests in the *Pre-Engineering Inventory* was established in 1942–43 with a fairly normal student population. Consequently, the battery will be appropriately adjusted to the abilities of students in the postwar era. If we assume that present entrance standards are relaxed over those normally operating, our experiments during the next year may have special significance for the postwar period. If we can determine within broad limits the minimum level of ability necessary to succeed in the engineering curriculum, this finding will be extremely useful when classrooms are crowded to overflowing and thousands of students not qualified for engineering study apply for admission to colleges of engineering.

What Can the Engineering Schools and the Aircraft Industries Do to Develop More Effective Engineering Personnel?*

By A. S. LEVENS

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Many estimates have been made to determine the number of engineers required to meet the needs of the armed forces and of industry. Only one real conclusion has been reached—there are not enough available. Where and how can we possibly meet the 1943 demand of approximately 50,000? † The total of this year's engineering graduates, which will not exceed 17,000, is only a partial solution to the problem. Of course, many more thousands who are not graduates will be trained to fill most of the positions in the war industries. Other solutions to the engineering personnel problem have been proposed. Among these are:

1. The recommendations ‡ of the special committee appointed by President Elliott. The following steps were set forth by this group.

a. Conserve and put to most effective use our existing staffs of engineers in the industries producing war materials and in the engineering schools training young men for specialized services in the armed forces and in the war industries.

b. Adapt all engineering, science, and management courses in colleges to the needs of war, both in the armed services and in the war industries.

c. Allocate engineers to each war activity on the basis of its relative needs, considering both the armed forces and the war industries. This allocation process should provide for those who plan to study engineering, for engineering students, engineering teachers, and engineers of mature experience.

d. Encourage women to undertake engineering and science courses in college.

e. Continue the support of the E. S. M. W. T. program.

f. Recognize the fact that the assignment of all able-bodied engineers to the armed forces where some may be called on to render service in fields where their training will not be used is a misdi-

* Presented at the 50th Anniversary Meeting, S. P. E. E. (Aeronautical), Chicago, Ill., June 18–20, 1943.

† Bulletin No. 3, April 13, 1943, War Manpower Commission, Bureau of Placement, National Roster of Scientific and Specialized Research.

‡ Page 305, JOURNAL OF ENGINEERING EDUCATION, December 1942.

rection of skill and is not in the best interest of the total war effort.

2. Occupational Bulletin No. 11, revised March 1, 1943, which provides for the deferment of all engineering students with the exception of those in enlisted reserve programs who can graduate by July 1, 1945, is another helpful means of continuing the flow of engineers into industry. This will cover practically all students now in school including 45,000 freshmen engineering students, the largest freshman class in history, and allow some continuing inflow to industry until 1945. Should the war continue beyond this date it may be necessary to divert some of the students from the Army-Navy training programs into a training program for industry.

3. The proposal * of President Heald who recently stated,

> Some plan is immediately needed to maintain a continuous flow of essential engineering personnel. To delay in meeting this need is to court disaster, if the war is to continue beyond 1944.
>
> There appear to be two possible plans for meeting these requirements. One is to enroll all able-bodied men students in the military training programs, and assign back to civilian tasks those who may be needed in war industry. This appears to be an expensive and inefficient procedure. The needs of the military services themselves are so great that there is little likelihood of their releasing any considerable number of men who have been trained for military service. . .
>
> The second possibility, and the one which seems most practicable, is the establishment of an industrial training corps paralleling those of the Army and Navy. Such a corps could enroll young men not physically qualified for military service, women, and a sufficient number of the physically fit to meet the most essential needs. Some provision for financial assistance should be made in order that selection of students could be entirely on the basis of ability, but it seems unlikely that the entire cost of their education would need to be borne by the Government.

4. The new Army and Navy programs. Military needs have brought about many changes and undoubtedly will continue to do so as the war activity fluctuates—today an A. S. T. P. and N. C. T. P. (V–12)—tomorrow, who knows? There is no doubt that the universities will continue to do everything possible to help meet the needs of our military units as well as those of industry.

5. Accelerated college programs which are now in effect in most schools.

6. Indoctrination programs for engineers from other fields to meet the specialized needs of the aircraft industry.

7. Training of more women. It has been estimated that approximately five million additional women will be needed in industry by the end of 1943. Part of this group can be trained for service in the engineering departments of the aircraft industry. It should be quite possible for our universities to undertake the training of senior women in the arts, science, and education colleges to provide needed engineering personnel. It is estimated that it will be possible to train at least 10,000. There is no reason why the universities should not grant full credit toward graduation for these special courses which might be given during the senior year. In fact, it is essential that we do so if we are to help fill the

* JOURNAL OF ENGINEERING EDUCATION, pp. 477–8, March 1943.

urgent need for trained persons. Certainly if the Curtiss-Wright program for the training of engineer "cadettes" and the recent Chance Vought Scholarship program at New York University are successful—and there is evidence to believe that they will be—we should find no difficulty in training senior college women for such positions as drafting, stress computing, materials testing, elementary stress analysis, and simple design. Upgrading of women who have had this preliminary training can be continued through courses given by the companies in coöperation with E. S. M. W. T.

During the semester just ended, twenty University of California senior women who had majored in mathematics were enrolled in a special course, *with regular university credit,* to fit them for beginning positions in the aircraft industry. This course, "Introduction to Aircraft Structures," dealt primarily with mechanics and strength of materials. It included a resumé of fundamental operations used in engineering computations (significant figures, tabular forms, slide rule, etc.); statics, including algebraic and graphical solutions of both two and three-dimensional trusses and frames; properties of areas (centroids and moments of inertia); strength of materials, including properties of materials, laboratory tests in tension and bending, joints under axial and eccentric loads, shear and moment diagrams for beams, shear and bending stress in beams, simple torsion; and compression members including the elementary theory of buckling and standard column formulas. Aircraft nomenclature, materials, and shapes were emphasized throughout. These students will be used in routine work connected with the structures, weights and other groups. With a minimum of specialized training on the job they could assume a reasonable amount of responsibility.

Engineering departments of many of the industries, especially those in the aircraft field, have used and will continue to use many persons who can be trained by short, intensive programs, both full-time and part-time. In a large measure this training is carried on through E. S. M. W. T., particularly with regard to the training of aircraft draftsmen and "draftsmenettes," loftsmen, and stress computers. Women so trained are able to proceed with simpler phases of the work, thus releasing men for military service or for more responsible work in industry.

Dean Crothers recently reported that the percentage of women trainees is still increasing. Under E. D. T. it was about 1 per cent; under E. S. M. D. T. about 9 per cent; under E. S. M. W. T. about 25 per cent. Since July 1, 1942, the University of California has given full-time training to 1,556 women for aircraft drafting, lofting, stress computing, materials testing, etc. Most of these courses consist of 480 hours of training covering a 12-week period. Qualified students who are accepted for this training are placed on the payrolls of the aircraft companies such as Consolidated, Lockheed, Douglas, North American, etc. at a salary of approximately $100 per month during the training period. The companies have found that the students who complete this training are doing remarkably well. Many classes have been given throughout the State of California. Very nearly all of the aircraft drafting courses were given by engineers from the aircraft companies; the mathematics and mechanics portion of

the courses by members of the engineering faculty of the University. In many cases it was necessary to advise and counsel the company's men in the art of teaching and the preparation and presentation of material. On the other hand we have learned a great deal from them in that many practical applications were used to stimulate interest. This was especially true of the part of the course dealing with descriptive geometry. We also learned that the drafting course would mean much more if such topics as aircraft materials and processes, sheet-metal layout, and an introduction to the elements of mechanics and strength of materials were included.

In addition, hundreds of part-time courses have been and are being given to provide supplementary training for those already employed. For the aircraft industries these include: aerodynamics, aircraft descriptive geometry, tooling, aircraft materials and processes, machine jig and fixture laboratory, stress analysis, aircraft design sketching, aircraft tooling inspection, aircraft instrumentation, etc. Since July 1, 1942, the University of California has offered part-time training to 28,359 men and 5,377 women in the courses mentioned above and in hundreds of other courses in engineering, science, and management. Upgrading of engineering personnel has been carried on both by E. S. M. W. T. and by industry itself. In a number of cases the aircraft companies have organized their own programs in stress analysis, layout work, and aerodynamics.

It is hoped that the experiences that we have gained from the E. S. M. W. T. program will bring about beneficial changes in the presentation of our own material. We have learned that descriptive geometry, for example, can be taught in a manner that will provoke considerable interest and enthusiasm on the part of the student. Former engineering graduates who have had an opportunity to review the work of the students are amazed at the results. A common remark is, "Gee, the stuff is useful after all." This has been possible largely through the introduction of many applications from both the aircraft and the shipbuilding industries. Changes in teaching of engineering drawing will undoubtedly come about as a result of the war training experience. We will find that the correlation of shop practice with drawing will give much better results than the isolation of these courses as unrelated units.

Another field that will receive considerable attention is productive tooling. The manner in which an effective program can be developed is described in R. G. Freeman's well-titled article, "The Maginot Line of Engineering Education." *

Faculty members who are participating in our war training program are learning a great deal about the presentation of technical material to groups who either have had no previous training or experience or who are very rusty in subjects they had studied twenty years or more ago. We are developing techniques that will undoubtedly result in more effective work with our regular students, and certainly with the Army and Navy groups assigned to the universities.

We should not be satisfied with our teaching methods nor with the content of our regular engineering courses. A careful review of all outlines and detailed material used in the war train-

* March, 1943 issue of *Mechanical Engineering.*

ing program should be made to determine desirable changes in our curricula. The E. S. M. W. T. experience and the needs of industry indicate that the colleges of engineering must give serious thought to the development of a program which is sufficiently flexible to provide for the training of two groups: (1) engineers who can fill the large general demand by industry, and (2) a relatively small group who have the ability to undertake advanced study and who can develop in the research fields. Many students are permitted to enter engineering schools—students who cannot possibly undertake the more advanced phases of learning. Yet, a goodly number of this group have a definite place in industry.

Engineering schools should give serious consideration to the development of an abbreviated program which will produce students who would be quite capable of filling many engineering positions which require no mathematics beyond useful trigonometry, and practical descriptive geometry. Why kid ourselves into believing that all of our students need or can undertake the advanced work offered in most engineering curricula? It would be much better to screen out the group that can handle advanced studies and prepare them for advanced design, research, and development work. Screening could take place during the freshman year. Under the usual four-year engineering program the student who is endowed with superior ability is lost because most of our teaching energies are spent in salvaging the larger group that would be better suited to the shorter program. A degree such as "Associate in Engineering" could be awarded to those who satisfactorily complete such a course.

The success of these proposals is predicated upon the maintenance of a high level of employment after the war. Otherwise, many companies are likely to return to their former practices of filling all positions with men of the advanced group—seeking the men in the upper quarter of the class, men who have leadership ability, outstanding personalities, excellent physical specimens (athletes preferred), etc.—forgetting that many well-trained 4F's are doing a fine job today. Selections should be made from both groups—those who will have completed the general advanced course and those who will have completed the shorter program of a more practical nature.

It is to be understood that this course is not to be regarded as one of low-grade training, but rather one best suited to the talents of a large number of students who could quite adequately fill positions as engineering aides, draftsmen, surveyors, computers, inspectors, laboratory technicians, etc. It should include much more training in detail design and drafting than is ordinarily included in our regular four-year program. Mr. Rex B. Beisel, General Manager of Chance Vought Aircraft, states, "The few men who are graduating from engineering colleges, not earmarked by the enlisted reserve system, are doing a job here. We do agree with you that most of them need much more training in detail design and drafting, hence our need for a long induction training period. We find many colleges either skip entirely, or do a slipshod job on this detail training, relying on the students' initiative to pick that up on his own. The assumption that a student acquires this training himself is usually false."

For a number of years some leaders

of industry have stated that the engineering schools were not giving the proper training, whereas others have said that they were doing an excellent job. Some faculty members have taken the stand that the engineering graduate was fulfilling his task, whereas others believe that we have fallen down on the job. Quite likely there is a bit of truth in the statements made by both the pros and the cons. It seems that a logical method of attack in solving our mutual problems would require active coöperation between industry and the schools. In part this is becoming possible through the E. S. M. W. T. program. However, we must carry on much further, especially in a post-war era.

Looking forward to closer coöperation between engineering schools and the aircraft industry, it is most gratifying to announce that the Consolidated-Vultee Aircraft Corporation has only recently completed plans to provide an integrated five-point program with an initial allotment of $50,000:

First: *Undergraduate scholarships* which will be open to highly recommended engineering students who will have completed their junior year. In addition to the annual stipend of $250, an opportunity to become oriented in the work of the aircraft industry will be provided through summer employment or preferably a full year's work experience before returning to the senior year.

Second: *Graduate fellowships* which will be open to graduate engineers who are highly recommended for graduate study and research in the field of aeronautical engineering. Conferences will be arranged for the successful candidate, the Corporation's representatives, and faculty members to discuss the problems to be investigated. Fellows who show promise would be encouraged to continue their studies and research for an additional year or two. Opportunities for practical experience through vacation employment would be essential to the development of the candidate.

Third: *Employment opportunities for engineering faculty during vacation periods.* This arrangement would bring about a closer relationship between the Corporation and the schools. It would result in more effective teaching and over a period of years should lead to the development of more useful engineers.

Fourth: *Exchanges between engineering faculty and the Corporation's engineering personnel.* It would provide a real opportunity to learn of each other's problems, and to develop sound methods for their solution.

Fifth: *Graduate study and research for the Corporation's engineers.* Members of the staff who have both the experience and the training would be given an opportunity to return for a year or more to selected schools for advanced study and research. Under the pressure of every-day work these men cannot devote much time to investigations which should be carried on if vital problems of the industry are to be solved. It would also strengthen the research programs of the engineering schools.

This program is a significant step forward in the development of a better product to handle the problems of engineering, both small and large. It will have a very beneficial effect on our university teaching and will also provide an opportunity for the engineers of industry to keep abreast of new developments. It is hoped that many aircraft companies will undertake similar programs. It is only through

an understanding of each other's problems that we may hope to develop more effective engineering personnel. The E. S. M. W. T. program has provided opportunities for closer relationships between the engineering schools and industry. The many contacts that have been made by the faculty will provide an excellent means for closer cooperation after the war. There is every reason to believe that a new era of engineering advancement is on its way—the development of more effective engineering personnel will come with "hand-in-hand" action between the schools and industry!

THE T-SQUARE PAGE

DEVOTED TO THE INTERESTS
OF ENGINEERING DRAWING
(Third of Four Issues)

WILLIAM E. STREET, *Editor*
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Drawing Competition

The drawing contest, which was so successful for several years, was discontinued in 1941 due to the emergency. At the annual Drawing Division meeting in June, 1942 it was decided to replace the drawing contest with a competition composed of one set of freshmen engineering drawings from each school participating. These drawings may represent the work of several different students. Bring or send your institution's set of drawings to the S.P.E.E. Meeting in Cincinnati this year. Professor W. E. Farnham, Chairman of the Division, will arrange for the judging.

Book Plate Competition

The library books of the Drawing Division of S.P.E.E., deposited in the Engineering Library of the University of Illinois, are to be decorated with a book plate. The February issue of the *Journal of Engineering Drawing* sets forth the rules and regulations governing this competition. Members of the Division or subscribers to the Drawing Journal are eligible. The committee welcomes your plates. They should be sent to R. R. Worsencroft, Editor—*Journal of Engineering Drawing*—University of Wisconsin.

Pictorial Production Speeded Up

Pictorial drawing has aided the speed up of production in industry immeasurably the last few years. This is especially true in the aircraft industry. Ellipse guides are now available to draw in the ellipses or pictorial circles for production illustrations. Location of the major and minor diameters for ellipses and selection of a suitable template are much faster than construction methods. These templates vary from 15° to 60° in 5° intervals. Those of 60°, 55°, 50°, 45°, and 40° have ellipses from $\frac{1}{8}$" to $\frac{3}{8}$" increasing by 32nds, then by 16ths to 1", then by 8ths to 2".

Templates of 35°, 30°, 25°, 20°, and 15°, progress as those above but start with sizes of $\frac{5}{32}$", $\frac{3}{16}$", $\frac{7}{32}$", $\frac{1}{4}$", and $\frac{3}{8}$" respectively.

Testing

Testing in engineering drawing and descriptive geometry in the crowded curricula of today should be scrutinized carefully. Some of the criteria of a good test are: easy to score,

comprehensive in scope, objective, and require a minimum amount of time to administer. Definite progress in the drawing testing field is being made. Clair V. Mann has done much to make drawing teachers conscious of the emphasis that testing deserves. The Army Specialized Training Drawing Achievement Test is interesting and shows progress. Several other comprehensive drawing tests have been developed and the S.P.E.E. Drawing Testing Committee working under the supervision of Clair V. Mann welcomes suggestions, sample questions and examinations for consideration. Drawing teachers have an excellent opportunity to develop a progressive series of drawing tests.

Drawing Division Program

JUNE, 1944

First Conference: (1) Isometric Approach to Descriptive Geometry by B. M. Aldrich, Oklahoma A. & M. College. (2) Teaching by Three Dimensional Pictures by John T. Rule, Massachusetts Institute of Technology.

Second Conference: (1) Business Meeting; (2) Committee Reports.

Luncheon and Dinner meetings to be held during the Convention.